The Development of Planar Fiber-Optic Microprobes for Rapid, Remote Assessment of Seafloor Bulk Properties and Sediment Grain Size

Mead Allison
Department of Geology
Tulane University
New Orleans, LA 70118
phone: (504) 862-3197 fax: (504) 865-5199 email: malliso@tulane.edu

Award #: N000140110358

LONG-TERM GOALS

The operational Navy seeks observational tools for rapidly determining the characteristics of near surface sediments in strategically important areas and in order to apply the predictive algorithms properly. The purpose of the proposed study is to develop an *in situ* fiber-optic microprobe that utilizes visible light radiation to determine sediment characteristics such as bulk density, mean grain size, porosity, and microfabric that is deployable over a wide range of seafloors from mud to sand (carbonate and siliciclastic). This tool, when deployed by the operational Navy, would allow for rapid mapping of sediment type and geotechnical properties by remote means, particularly when used in concert with existing probe technology (e.g., sediment resistivity probes). Potential deployment platforms include autonomous ROV's, wire-deployed profilers, and bottom tripods.

OBJECTIVES

The principle objective of the present research is to develop and test a probe that could be designed for fully *in situ* ocean conditions (including electronics) and that could be mounted with other devices (sediment resistivity probes, suspended sediment concentration sensors, etc.) on bottom deployed tripods or operated from the surface attached to water column/sediment profilers. The fiber-optic sensor would be deployable in a wide variety of sediment types to determine fully the nature of the sensor response to allow its calibration for use as a sediment density probe in water column/seabed and a grain character probe (grain size and orientation).

APPROACH

Year 1 of this project is a laboratory phase. In this phase, a probe will be designed for commercial fabrication. This probe will be tested in a wide variety of sediments in the laboratory to determine its response/calibration characteristics. Year 2 will be a field phase of testing of the finished probe package. This will include the hardware and software necessary to deploy on a field tripod mounted in a shallow water system. Four League Bay, Louisiana is the tentative field deployment site. This area is 1-2 m deep and situated near the Atchafalaya River outlet so that it is undergoing rapid sedimentation and erosion events (cold fronts). In addition, the area has been noted as a site of fluid mud formation—a topic of interest to the Navy and the scientific community as a primary mechanism for transporting and burying shelf sediment adjacent to large river discharges. This will provide useful scientific data as well as a thorough test of probe capabilities. In this deployment, electronics and power supply will not be submersible. At the end of Year 2, enough information should be available to

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **The Development of Planar Fiber-Optic Microprobes for Rapid, Remote Assessment of Seafloor Bulk Properties and Sediment Grain Size**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Geology,Tulane University,,New Orleans,,LA, 70118**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The operational Navy seeks observational tools for rapidly determining the characteristics of near surface sediments in strategically important areas and in order to apply the predictive algorithms properly. The purpose of the proposed study is to develop an in situ fiber-optic microprobe that utilizes visible light radiation to determine sediment characteristics such as bulk density, mean grain size, porosity, and microfabric that is deployable over a wide range of seafloors from mud to sand (carbonate and siliciclastic). This tool, when deployed by the operational Navy, would allow for rapid mapping of sediment type and geotechnical properties by remote means, particularly when used in concert with existing probe technology (e.g., sediment resistivity probes). Potential deployment platforms include autonomous ROV???s, wire-deployed profilers, and bottom tripods.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

design a simpler, more automated planar probe that would be useful to the operational Navy as well as other oceanographic investigators. This system would include an underwater electronics package that would hold the light source and receiving spectrometer for the microprobe. Datalogging hardware and software will have to be designed to control movement of the probe, data collection, and data storage. Finally, the probe will be integrated with deployment packages used by other investigators examining sediment characteristics such as bulk properties. It is anticipated that this package could be made ready for a number of upcoming ONR-supported field experiments including EUROSTRATAFORM and ONR Mine Burial Initiative.

WORK COMPLETED

Since the beginning of the project in the Spring of 2001, several major tasks have been completed:

1. *Probe Design and Fabrication* – After laboratory testing a number of configurations for the planar, fiber-optic probe, a final design was decided upon that uses dual, 200 micron UV/VIS fibers in a 10 cm, stainless steel probe hull. Ocean Optic, Inc. of Dunedin, Florida was contracted to fabricate a prototype of this design. Corporate involvement was deemed necessary to arrive at a reproducible design, after much experience with fabrication in my laboratory. This prototype has been tested extensively and is successful (see below)

2. *Flume Experiments* -- As all tests to date on the probe had been in core material in the laboratory, it was determined that the next step would be to test probe response in a laboratory flume experiment using intact core material and simulating real world marine conditions. To this end, in July 2001 a set of successful experiments were conducted on the LUMCON flume at Cocodrie, Louisiana using the prototype Ocean Optics probe.

3. *Design of Autonomous Array* – As part of the ONR DURIP proposal process in August 2001, a prototype submersible deployment system (tripod) for the microprobes was designed. A proposal was submitted with R. Wheatcroft (OSU), who is interested in similar tripod design, for inserting electrical resistivity probes. If funded, this venue and design would allow the results of the present funded project to transition rapidly to a fully submersible system.

RESULTS

Figures 1 and 2 present results from the flume experiments at LUMCON with the prototype Ocean Optics probe. These results demonstrate 1) the successful design of the prototype, 2) the value of the probe as a sediment density sensor on micro-depth scales over a wide range of sediment concentrations from water column to seabed, and 3) the value in real world studies of tracking high-frequency effects to the bed over length scales from microns to centimenters. The flume experiment included co-measurement with a number of other sensors (geochemical microprobes, ADV current meters, acoustic seabed mappers, etc.) that will be necessary for interpreting microprobe data on a DURIP-type deployment. As such, the “spin-up” timing for deployment of a fully submersible, autonomous tripod has been shortened, increasing the potential of this system to contribute to EUROSTRATAFORM and/or Mine Burial.

IMPACT/APPLICATIONS

The development of a robust probe that can be calibrated as a sediment sensor holds great promise for its use in remote deployments by divers or ROV/AUV's. It's low cost ($300 for the prototype) also suggests the possible use of these probes on expendable, ship-deployed sensor packages for relaying information about bottom type in areas of strategic importance to the Navy. In terms of scientific value, the flume experiment demonstrates its value for examining small-scale, near bed sedimentary processes in turbid environments.

TRANSITIONS

The early results of this development have not been transmitted to others to date.

RELATED PROJECTS

None

PUBLICATIONS

None

PATENTS

None

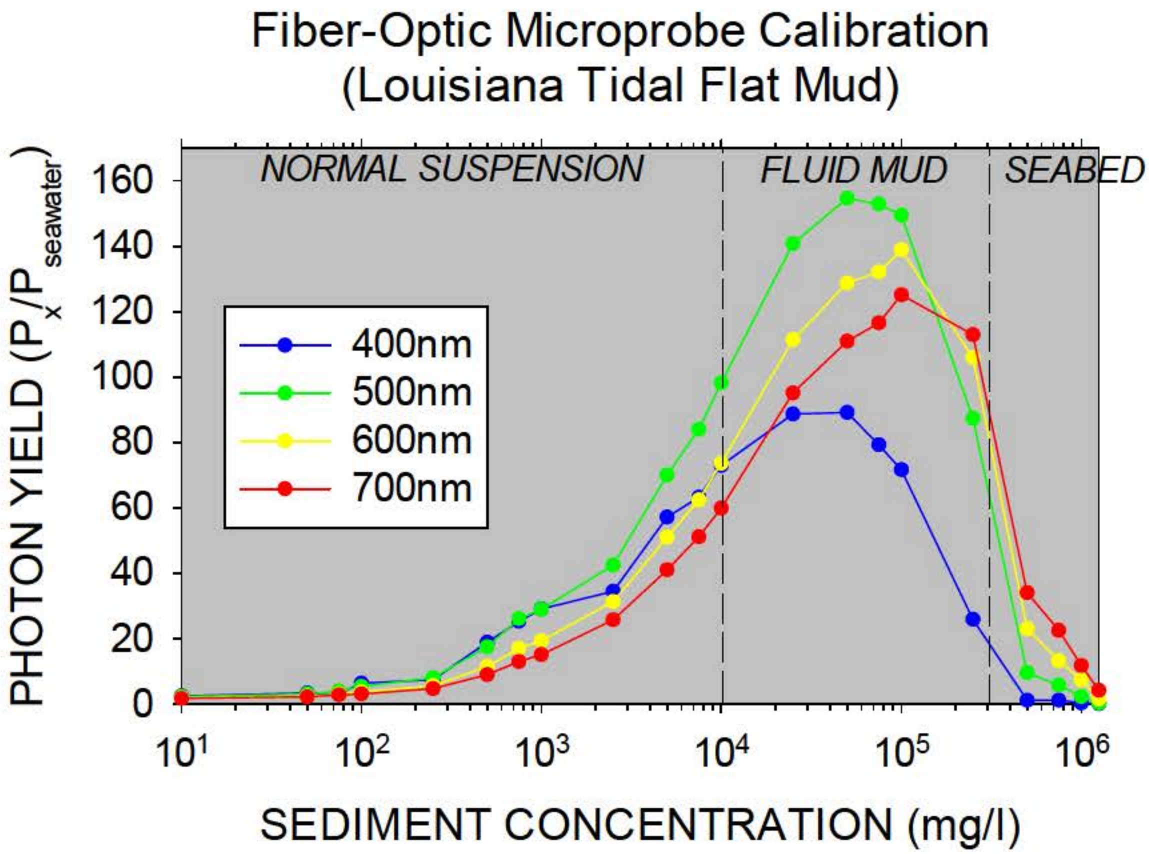

Figure 1. Fiber-optic microprobe calibration curve for sediment concentrations (porosity). Photon yield represents the amount of light measured by the probe ratioed to the value for filtered seawater. This curve was calculated in the laboratory using weighed sediment/water mixtures from a silty clay, south Louisiana tidal flat. The sediment was taken from the same site as the flume experiment core discussed in the text and Fig. 2. This figure demonstrates that the microprobe can be used as a sediment density probe at an enormous range of concentrations from water column (mg/l to g/l) to fluid mud (10-300 g/l) to seabeds of at least 65% porosity (the limit measured in this calibration). No other existing concentration sensor (electrical resistivity, transmissometer, optical backscatterance, nephelometer, etc.) has this range of applicability. Also, the relative behavior of short (400 nm) vs. long (700 nm) wavelengths can be used to differentiate between similar photon yields on the high and low concentration sides of the curve. This is accomplished by noting that short wavelengths give the highest yields at concentrations less than about 100 mg/l. At concentrations greater than about 200,000 mg/l (fluid mud), the longest wavelengths give the highest photon yield. This relationship occurs because there is a transition from water column scattering effects in low concentrations that preferentially absorb long wavelengths, to dense, particle scattering processes that more efficiently scatter short wavelengths.

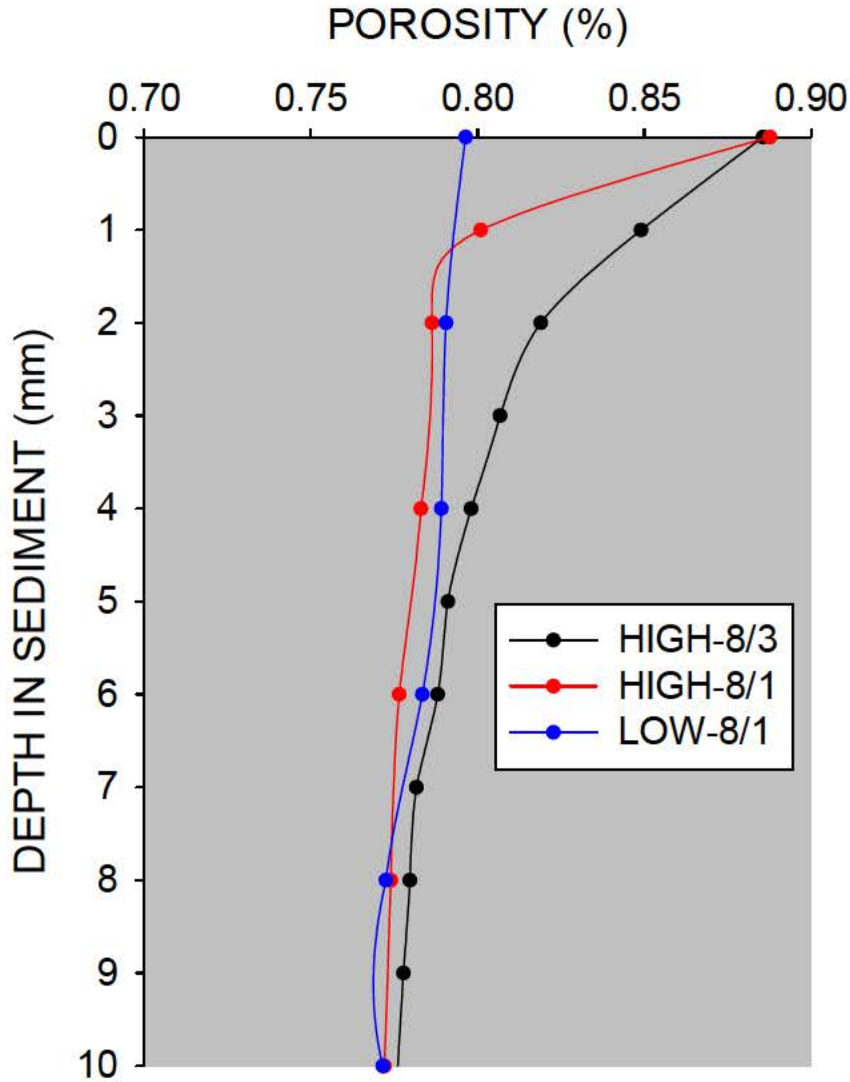

Figure 2. Fiber-optic microprobe measurements in a sediment core mounted in the LUMCON flume—see text for experimental setup. Downcore profiles were measured at the start of the experiment using no currents on 8/1 (Low-8/1), a second time after one hour of currents at 21 cm/sec (High-8/1), and 48 hours later with the current at 21 cm/sec for the entire intervening time. Note that porosities increase significantly in the upper 1 mm of the core with the application of current and that this porosity increase extends to ~4mm with continued flow. This is interpreted to indicate the current flow has increased diffusion/advection in the upper sediments sufficient to increase porosity. The most important result is the ability of the probe to measure processes over this small depth scale.